of the Perigenesis of the plastidule, and with it the theory of dynamical differentiation—because the latter is no longer a hypothesis—forever relegates teleological doctrines to the category of extinct ideas. No matter how much our ideas may need to undergo modification, some similar hypothesis must eventually hold sway over the minds of biological thinkers, as the facts of science point in that direction and in no other.

It has been suggested in conversation by my friend Dr. A. J. Parker, of this city, that the assumption of the *plastidule* as the ultimate physical unit of living matter was unnecessary, as it consisted merely in naming the protoplasm molecule, and it must be admitted that this view of the case is not without reason. Prof. Haeckel, it is to be supposed, however, adopted this name merely to distinguish his own provisional hypothesis from that of his acknowledged master. The word *plastidule* is a diminutive of the current word *plastid*, which is synonymous with cell, and therefor, implies and correctly, too, that the *plastids* are aggregates of varying numbers of plastidules, which are for physical reasons the smallest possible or conceivable units of living matter, of which even the most minute *gemmæ* or budding cells are composed.

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ABSORPTION OF WATER BY THE LEAVES OF PLANTS.

BY ALFRED W. BENNETT, M.A., B.S., F.L.S.

ALTHOUGH gardeners universally maintain that growing plants have the power of absorbing water through their leaves, both in the liquid and the gaseous form, in addition to the power of suction through the root, yet the contrary theory has been in favor during recent years among vegetable physiologists. The first recorded experiment, of any value on the subject, was about the year 1731 by Hales, as described in his "Vegetable Statistics;" the conclusion to which he came being that "it is very probable that rain and dew are imbibed by vegetables, especially in dry seasons." This result was confirmed by Bonnet in 1733. A century later, however, in 1857, Duchartre, experimenting on the absorptive power of plants, came, after considerable wavering, to the conclusion that rain and dew are not absorbed by the leaves of plants. This opinion has been, with but little exception, held by all physiologists during the last twenty years, notably by

DeCandolle and Sachs; the explanation offered of the fact that withered plants revive when placed in moist air or when the leaves are moistened, being that transpiration is thus stopped, or is more than counterbalanced by the root-absorption. In his "Text-book of Botany" (English edition, p. 613) Sachs says: "When land plants wither on a hot day and revive again in the evening, this is the result of diminished transpiration with the decrease of temperature and increase of the moisture in the air in the evening, the activity of the roots continuing; not of any absorption of aqueous vapor or dew through the leaves. Rain again revives withered plants, not by penetrating the leaves, but by moistening them and thus hindering further transpiration, and conveying water to the roots, which they then conduct to the leaves." McNab has, however, proved that leaves do transpire, even in a moist atmosphere, provided they are exposed to the action of light. The result of recent experiments, conducted by Boussingault in France, and by the Rev. George Henslow, in England, seem to force us to return to the earlier theory held before the time of Duchartre.

Boussingault's experiments relate not only to the absorption of water by leaves, but also to transpiration under various atmospheric conditions. The first experiments were as to the amount of transpiration from the Jerusalem artichoke in sunshine, in shade and by night. This he found to be hourly, for every square metre of foliage, sixty-five grammes in sunshine, eight grammes in the shade, and three grammes during the night. In the vine the corresponding numbers were thirty-five grammes in sunshine, eleven grammes in shade, 0.5 grammes by night. He reckoned that an acre of beet could give off, in the course of twenty-four hours, the enormous amount of between 8000 and 9000 kilogrammes of water, and a chestnut tree, thirty-five years old, sixty litres of water in the same time. The next question investigated was whether the absorption of water by plants, and the ascent of the sap, are due to the force resulting from transpiration on the surface of the leaves, or whether the roots exercise also a certain amount of force to this end. In the case of mint, a plant with roots, showed an hourly evaporation per square metre of eighty-two grammes in the sunshine, and thirty-six grammes in the shade; without roots the evaporation was sixteen grammes in sunshine, fifteen grammes in shade. The effects

of pressure on the absorption were next examined. A chestnut branch dipped in water was found to transpire hourly sixteen grammes per square metre; when inserted into a tube of water and subjected to the pressure of a column of water two and a-half metres high, the evaporation amounted to fifty-five grammes per square metre per hour, and the branch, at the end of five hours, weighed more than at the commencement. As to the effect of the epidermis in restraining evaporation, he found that an apple deprived of its skin loses fifty-five times as much water in the same time as one with its skin entire; while similar experiments in the case of a cactus leaf showed a difference in the proportion of fifteen to one. Losses by rapid evaporation lessen appreciably the physiological energy of leaves. Thus an oleander leaf containing sixty per cent. of water, when introduced into an atmosphere containing carbonic acid gas, decomposed sixteen c. cm. of the gas; one containing thirty-six per cent. of water decomposed eleven c. cm.; while one containing twenty-nine per cent. of water was without action. As respects the relative power of evaporation possessed by the upper and under surfaces of leaves, he found the average proportien in a dozen different kinds to be as one in the former to 4.3 in the latter case.

Boussingault then proceeded to investigate the question of the ability of leaves to replace the roots of a plant in serving as the agent of absorption. A forked branch of lilac was so placed that one portion was immersed in water in a reversed position, while the other was exposed to the atmosphere, the superficies of foliage in both portions being the same. The transpiration from the exposed portion was found to be the same as under normal circumstances, and after the lapse of two weeks the foliage was as fresh as at the commencement, showing that the submerged leaves were fully able to replace the roots in supplying the shoot with moisture. A vine-shoot half plunged in water maintained a normal evaporation in the free foliage, and remained fresh for over a month. An oleander shoot, under similar circumstances maintained its normal appearance for four months. With the artichoke it was found necessary that the amount of surface of leaves beneath the water should be four times that above it. A number of experiments, with regard to the power of leaves to absorb water in the state of vapor from a saturated atmosphere, showed that they could do this only when they had previously lost a por-

tion of their water of constitution, *i. e.*, that which is essential to their normal existence. Thus a wilted branch of periwinkle, weighing four grammes, after remaining for a day and a-half in an atmosphere saturated with aqueous vapor, weighed 4.2 grammes; after twelve hours immersion in water it weighed 9.4 grammes. His last experiments related to the power of leaves to absorb aqueous solutions. Drops of water containing 0.2 per cent. of calcium sulphate in solution were placed on the leaves of a great variety of plants under conditions favoring absorption, and protected from evaporation by inverted watch glasses with greased edges. In most instances the drops were entirely absorbed, leaving no trace of the mineral matter. As in the case of pure water, the under surface of the leaf absorbed much more rapidly than the upper surface. Solutions of potassium sulphate and nitrate gave corresponding results; the absorption of solutions of sodium chloride and ammonium nitrate were not so perfect. It is obvious that these results must considerably modify the view at present held by physiological botanists, that the small quantity of ammonium carbonate contained in the air, which is believed to be the sole source of the nitrogen in the tissues and secretions of plants, can only be absorbed by the roots after having been brought down to the soil by rain.

Mr. Henslow's experiments, as detailed in a paper read at a recent meeting of the Linnæan Society of London, are altogether in harmony with those of the French professor. The results of a very large number of experiments extending over several years, may be epitomized as follows:

1. *The absorption of water by internodes.*—The experiment consisted of wrapping up one or more internodes of herbaceous plants in saturated blotting-paper, and in noting the effects. As a rule the leaves on the shoots rapidly perished, showing that transpiration was too great for the supply. The stems, however, kept fresh for different periods up to six weeks.

2. *Absorption by leaves to see how far they could balance transpiration in others on the same shoot.*—The general result is that as long as the leaves remain green and fresh in or on water, they act as absorbents; but that the leaves in air keep fresh or wither according as the supply equals or falls short of the demand.

3. *To test how far leaves on a shoot can nourish lower ones on the same.*—It appears that it is quite immaterial to plants whether they be supplied with water from the absorbing leaves being above or below those transpiring. Water flows in either direction equally well.

4. *Leaves floating on water.*—It was found that one part of a leaf can nourish another part for various periods, though the edges out of water died first.

5. *Absorption of dew.*—A long series of cut leaves and shoots were gathered at 4 P. M., then exposed to sun and wind for three hours, then carefully weighed and exposed all night to dew. At 7.30 A. M., after having been dried, they were weighed again, and all had gained weight, and quite recovered their freshness, proving that slightly wetted detached portions do absorb dew.

6. *Imitation dew.*—Like results followed from using the "spray," by which dew could be exactly imitated.

7. *Plants growing in pots*, and of which the earth was not watered, were kept alive by the ends of one or more shoots being placed in water; *e.g.*, *Mimulus moschatus* not only grew vigorously and developed auxiliary buds into shoots, but also blossomed.

By these interesting experiments the physiological botanist is again placed in harmony with the gardener who syringes his plants not merely for the purpose of washing off dust and insects, but in order to facilitate the actual absorption of water by the surface; and with the field botanist who sprinkles the plants in his vasculum with water to keep them fresh till he reaches home. Mr. Henslow concludes with the following hints as to preparing bouquets of cut flowers:

If some plants have buds upon them, let the stalks long, and allow a few leaves to remain on and be also immersed in the water, and the buds will then be often found to expand successively. The cut end, to be more absorbent than it otherwise would be, should be again cut off under water. If the blossoms be on a ligneous stem, as of lilac, then the loss of water by evaporation is greater than the woody stalk can supply, so that in this case the addition of leaves in the water will greatly aid, and retain the bunch of flowers fresh for a longer time. On the other hand, if a blossom be already about to shed its petals, then the additional supply of water furnished by the leaves on the stalk appears to hasten the coming dissolution, and the flower perishes rather sooner than it would otherwise do. The water must be changed every day, and the submerged leaves must be lightly wiped with a cloth, as by endosmotic action they soon become more or less coated with mucus. No leaves must be in water unless perfectly green and of vigorous growth.